EECS 522 RF Power Amplifier with Cartesian Feedback

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Outline

• Motivation
• Power Amplifier Design
• Mixer Design
• Cartesian Feedback
• System Results
Motivation

- RF transmitter for communication
  - 2.4GHz
- Improve linearization with feedback
Power Amplifier Overview

- Tradeoffs in PA design:
  - Efficiency
  - Linearity
- Run PA close to saturation for efficiency, then use feedback to improve linearization
- RF PAs have a mixer to up convert the signal from baseband to RF
PA Schematic

- Straightforward design
- Power efficient
- Differential to reject RF coupling to power supplies
PA Simulation Results

<table>
<thead>
<tr>
<th>Specification</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAE</td>
<td>48 %</td>
</tr>
<tr>
<td>1dB Compression (input referred)</td>
<td>-1.89 dBm</td>
</tr>
<tr>
<td>Max Output Power</td>
<td>12 dBm</td>
</tr>
</tbody>
</table>
Mixer Schematic

- Better isolation
- LO and RF rejection at IF output
- Higher linearity
- Good suppression of even order spurious product
- Less source voltage noise
Mixer Simulation Results

<table>
<thead>
<tr>
<th>Specification</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1dB Compression (input referred)</td>
<td>-8.02 dBm</td>
</tr>
<tr>
<td>IIP3</td>
<td>1.57 dBm</td>
</tr>
<tr>
<td>RF to IF Isolation</td>
<td>77.63 dB</td>
</tr>
<tr>
<td>LO to IF Isolation</td>
<td>47.50 dB</td>
</tr>
<tr>
<td>LO to RF Isolation</td>
<td>95.88 dB</td>
</tr>
<tr>
<td>Conversion Gain</td>
<td>4.65 dB</td>
</tr>
<tr>
<td>Noise Figure</td>
<td>21.73 dB</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>3.64 mW</td>
</tr>
</tbody>
</table>

![Mixer 1dB Compression and IIP3](image.png)
Cartesian Feedback

- Improves distortion by increasing the linearity through feedback
- Uses two independent I and Q feedback loops
- Robust for PVT variation

[Dawson]
H(s) Loop Filter

- Slow rolloff
  - 45 deg phase for stability

\[ H(s) \approx \frac{K}{\sqrt{s}} \]
System Simulations

Ideal

Open Loop

Closed Loop

RF input

RF output
## System Simulations

### 1dB Compression Point for System

<table>
<thead>
<tr>
<th>Specification</th>
<th>Open Loop</th>
<th>Closed Loop</th>
</tr>
</thead>
<tbody>
<tr>
<td>1dB Compression (input ref)</td>
<td>-12 dBm</td>
<td>-5 dBm</td>
</tr>
<tr>
<td>Max Output Power</td>
<td>24 dBm</td>
<td>22 dBm</td>
</tr>
</tbody>
</table>

Red = Open Loop
Black = Closed Loop

1dB Compression Point
## Results Summary

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1dB Compression (input referred)</td>
<td>-10 dBm</td>
<td>-31 dBm</td>
<td>-12 dBm</td>
<td>-5 dBm</td>
</tr>
<tr>
<td>Max Output Power</td>
<td>21.8 dBm</td>
<td>8 dBm</td>
<td>24 dBm</td>
<td>22 dBm</td>
</tr>
<tr>
<td>Area</td>
<td>-</td>
<td>-</td>
<td>1.15mm²</td>
<td>&gt;1.15mm²</td>
</tr>
</tbody>
</table>
Future Works

- $H(s)$ implementation
- Linearity of feedback mixer
- Phase alignment design
Questions?
References


